Ch 16 Acid and Base Practice Problems:

Name KEY
Period _____

1. For the following aqueous equilibria, designate the Brønsted-Lowry conjugate acid-base pairs and establish the weaker side:

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a. $NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$
BASE ACID C.ACID C.BASE
($NH_3 + H_2O$ is the weaker side) – (OH^- is a strong Base.)

b. $HCN(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CN^-(aq)$
ACID BASE C.ACID C.BASE
weak side (HCN is a weak acid; H_2O is a weak Base) H_3O^+ is a strong Acid

c. $NH_4^+(aq) + CO_3^{2-}(aq) \rightleftharpoons NH_3(aq) + HCO_3^-(aq)$
Acid Base C.Base C.Acid
stronger side (NH_4^+ is stronger acid; CO_3^{2-} is strong Base) (HCO_3^- is a very weak acid. NH_3 is weaker Base.) weak

2. Write the name and formula for the conjugate bases of the following:

a. HNO_2 remove H^+ = NO_2^- (Nitrite)

b. H_2SO_4 remove H^+ = HSO_4^- (Bisulfate)

c. $H_2PO_4^-$ remove H^+ = HPO_4^{2-} (monohydrogen phosphate)

d. HF remove H^+ = F^- (Fluoride)

e. CH_3CO_2H remove H^+ = CH_3COO^- (Acetate)

3. Complete the Brønsted-Lowry equilibria, label the components acid or base, and pair up the conjugate acid-base pairs:

a. $HSO_4^- + H_2O \rightarrow SO_4^{2-} + H_3O^+$
ACID BASE C.Base C.ACID
or $HSO_4^- + H_2O \rightleftharpoons H_2SO_4 + OH^-$
Base Acid C.ACID C.Base

b. $NH_3 + H_2O \rightarrow NH_4^+ + OH^-$
Base Acid C.Acid C.Base

c. $CN^- + H_2O \rightarrow HCN + OH^-$
Base Acid C.ACID C.Base

d. $H^- + H_2O \rightarrow H_2 + OH^-$
Base Acid C.ACID C.Base

e. $HClO_4 + H_2O \rightarrow ClO_4^- + H_3O^+$
Acid Base C.Base C.Acid

4. Is the monohydrogenphosphate ion HPO_4^{2-} amphiprotic?

If so, write the formulas of its conjugate acid and its conjugate base.

$PO_4^{3-} \xleftarrow{\text{Acid}} (HPO_4)^{2-} \xrightarrow{\text{Base}} H_2PO_4^-$

C. Base — C. Acid.

5. Of the following acids, determine

a. The strongest acid
b. The acid that produces the lowest concentration of hydronium ions per mole of acid
c. The acid with the strongest conjugate base
d. The diprotic acid
e. The strong acid
f. The acid with the weakest conjugate base

→ $HNO_3(aq) + H_2O(l)\ H_3O^+(aq) + NO_3^-(aq)\ K_a = \text{very large}$ ← (A, E, F)

$HSO_4^-(aq) + H_2O(l)\ H_3O^+(aq) + SO_4^{2-}(aq)\ K_a = 1.2 \times 10^{-2}$

$HCN(aq) + H_2O(l)\ H_3O^+(aq) + CN^-(aq)\ K_a = 4.0 \times 10^{-10}$ ← (B)

$H_2CO_3(aq) + H_2O(l)\ H_3O^+(aq) + HCO_3^-(aq)\ K_a = 4.2 \times 10^{-7}$ ← (D)

→ $NH_4^+(aq) + H_2O(l)\ H_3O^+(aq) + NH_3(aq)\ K_a = 5.6 \times 10^{-10}$ ← (C)

$HF(aq) + H_2O(l)\ H_3O^+(aq) + F^-(aq)\ K_a = 7.2 \times 10^{-4}$

6. Write net ionic acid-base reactions for:

a. The reaction of acetic acid with aqueous ammonia solution

$HC_2H_3O_2 + NH_3 \rightarrow NH_4^+ + C_2H_3O_2^-$

b. The reaction of hydrofluoric acid with sodium hydroxide

$HF + Na^+ + OH^- \rightarrow Na^+ + F^- + HOH$

$HF + OH^- \rightarrow H_2O + F^-$

c. The reaction of ammonium chloride with potassium hydroxide

$NH_4^+ + OH^- \rightarrow NH_3 + H_2O$

d. The reaction of sodium bicarbonate with sulfuric acid

$Na^+ + HCO_3^- + H^+ + HSO_4^- \rightarrow H_2CO_3 + HSO_4^- + Na^+$

$HCO_3^- + H^+ \rightarrow H_2CO_3$

$HCO_3^- + H^+ \rightarrow CO_2 + H_2O$

e. The reaction of chlorous acid with aqueous ammonia solution

$NH_3 + HClO_2 \rightarrow NH_4^+ + ClO_2^-$

f. The reaction of disodium hydrogen phosphate with acetic acid

$2Na^+ + HPO_4^{2-} + 2HC_2H_3O_2 \rightarrow 2Na^+ + 2C_2H_3O_2^- + H_3PO_4$

$HPO_4^{2-} + 2HC_2H_3O_2 \rightarrow H_3PO_4 + 2C_2H_3O_2^-$

or

7. What is the pH of

a. 0.0010 M HCl solution?

HCl ionizes 100% $\Rightarrow [H^+] = 0.0010\ M$

$pH = -\log[H^+] = -\log 0.0010 = \boxed{3}$

b. 0.15 M KOH solution?

KOH ionizes 100%

$pOH = -\log[OH^-]$

$= -\log[0.15]$

$pOH = 0.824$

$pH + pOH = 14$

$pH = 14 - pOH$

$= 14 - 0.824$

$= \boxed{13.17}$

c. 10^{-8} M HNO_3 solution?

HNO_3 ionizes 100%

$\therefore [H^+] = 1 \times 10^{-8}$

$pH = -\log[H^+]$

$= -\log[1 \times 10^{-8}] = \boxed{8}$

8. List the following substances in order of increasing acid strength:

H_2O, H_2SO_3, HCN, $H_2PO_4^-$, NH_4^+, $[Cu(H_2O)_6]^{2+}$, NH_3, H_3O^+, HCO_2H, HCl.

1×10^{-16} 1.7×10^{-2} 4.9×10^{-10} 6.2×10^{-8} 1×10^{-8} 1×10^{-14} -1.7 1.84×10^{-4} 1×10^{7}

H_2O, NH_3, HCN, $Cu(H_2O)_6^{2+}$, $H_2PO_4^-$, NH_4^+, HCO_2, H_2SO_3, H_3O^+, HCl

9. Complete the table for each aqueous solution at 25°C.
State whether the solutions are acidic or basic.

$[H^+][OH^-] = 1 \times 10^{-14}$

$[H_3O^+]$	$[OH^-]$	pH	pOH	acidic or basic
2.0×10^{-5}	5×10^{-10}	4.70	9.3	Acidic
5.62×10^{-7}	1.78×10^{-8}	6.25	7.75	Acidic
1.76×10^{-13}	5.6×10^{-2}	12.75	1.25	Basic
1.58×10^{-5}	6.31×10^{-10}	4.8	9.20	Acidic
8.7×10^{-10}	1.15×10^{-5}	9.06	4.94	Basic

10. What is the pH of a solution that contains 2.60 grams of NaOH in 250 mL of aqueous solution?

$\frac{2.60\ g\ NaOH}{0.250\ L} \left| \frac{1\ mol\ NaOH}{39.997\ g\ NaOH} \right. = 0.260\ M\ NaOH = 0.260\ M\ OH^-$

$pOH = -\log[OH^-]$

$= -\log[0.260]$

$pH + pOH = 14$

$pH = 14 - pOH$

$pH = 14 - 0.585$

$pH = \boxed{13.41}$

11. If the pH of a sample of rainwater is 4.62, what is the hydronium ion concentration $[H_3O^+]$ and the hydroxide ion concentration $[OH^-]$ in the rainwater?

12. A 0.12 M solution of an unknown weak acid has a pH of 4.26 at 25°C. What is the hydronium ion concentration in the solution and what is the value of its K_a?

13. Hydroxylamine is a weak base with a $K_b = 6.6 \times 10^{-9}$. What is the pH of a 0.36 M solution of hydroxylamine in water at 25°C?

#11) $pH = 4.62$

$pH = -\log [H^+]$

$10^{-pH} = [H^+]$

$10^{-4.62} = [H^+]$

$2.399 \times 10^{-5} = [H^+]$

$pOH = 14 - pH$

$pOH = 14 - 4.62$

$pOH = 9.38$

$pOH = -\log [OH^-]$

$10^{-pOH} = [OH^-]$

$10^{-9.38} = [OH^-]$

$4.167 \times 10^{-10} = [OH^-]$

check!

$[H^+][OH^-] = 1.0 \times 10^{-14}$

$(2.399 \times 10^{-5})(4.167 \times 10^{-10}) = 9.9999 \times 10^{-15}$ yes that is close

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#12)

	HA	$\rightleftharpoons$	H^+	+	A^-
I	0.12		0		0
C	$-5.495E^{-5}$		$+5.495_{E^{-5}}$		$5.495E^{-5}$
E	$(0.12 - 5.495E^{-5})$		$(5.495_{E^{-5}})$		$(5.495_{E^{-5}})$

$pH = 4.26$

$pH = -\log [H^+]$

$10^{-pH} = [H^+]$

$10^{-4.26} = [H^+]$

$5.495 \times 10^{-5} = [H^+]$

$K_a = \dfrac{[H^+][A^-]}{[HA]} = \dfrac{(5.495 \times 10^{-5})(5.495 \times 10^{-5})}{(0.12)} = 2.51 \times 10^{-8} = K_a$

13) $K_b = 6.6 \times 10^{-9}$

$$K_b = \frac{[HB^+][OH^-]}{[B]} = 6.6 \times 10^{-9} = \frac{[x][x]}{(0.36)}$$

$$6.6 \times 10^{-9} = \frac{x^2}{0.36}$$

$$2.376 \times 10^{-9} = x^2$$

$$4.874 \times 10^{-5} = x = [OH^-]$$

$$pOH = -\log [OH^-]$$

$$= -\log 4.874 \times 10^{-5}$$

$$pOH = 4.31$$

$$pH = 14 - pOH$$

$$= 14 - 4.31$$

$$\boxed{pH = 9.69}$$